

Review

Epidemiological clues to preventing colic

D.C. Archer *, C.J. Proudman

Faculty of Veterinary Science, University of Liverpool, Leahurst, Neston, The Wirral CH64 7TE, UK

Abstract

Colic remains a significant problem in the horse in terms of welfare and economics; in some equine populations it is the single most common cause of death. Many causes of colic are cited in the equestrian and veterinary literature but little scientific evidence exists to substantiate these theories. Recent epidemiological investigations have confirmed that colic is complex and multi-factorial in nature. Studies have identified a number of factors that are associated with increased risk of colic including parasite burden, certain feed types, recent change in feeding practices, stabling, lack of access to pasture and water, increasing exercise and transport. These findings are reviewed together with examples of management practices that may be altered to reduce the incidence of specific types of colic. This is an opinionated, not a systematic, review focusing on those areas that are considered most relevant to the practitioner.

© 2005 Elsevier Ltd. All rights reserved.

Keywords: Horse; Colic; Epidemiology; Risk-factors; Parasites; Nutrition; Management

1. Introduction

Colic, a term used to describe abdominal pain, usually gastrointestinal in origin, has been recognised as a disease of the horse for centuries. It is a significant disease due to compromise of equine welfare and its economic impact; in the USA the annual cost of colic has been estimated at \$115.3 million, losses due to death accounting for 66% of this figure (Traub-Dargatz et al., 2001).

Colic is reported to be the single most common cause of death in some horse populations, representing over a quarter of all deaths in one study (Tinker et al., 1997a). There are many anecdotal reports of causes, and prevention, of colic in the veterinary and equestrian literature but little scientific evidence to substantiate these theories. Recent epidemiological studies have shown that colic, like most non-communicable diseases, is complex

and multi-factorial in nature (Reeves, 1997). Identification of risk factors, particularly those that are modifiable, may enable disease-prevention strategies to be developed. The results of these epidemiological studies form the basis of best, current, evidence-based advice that can be given to horse owners on prevention of colic in the horse.

An electronic search for papers was conducted using MEDLINE pubmed (<http://www.pubmed.gov>) using a variety of search words such as equine, horse, colic, epidemiology, anthelmintic and gastrointestinal. Papers that were not identified on these searches but referenced to in other papers were selected in addition to papers in journals not referenced on MEDLINE and proceedings of equine conferences known to the authors. In this article we review the risk-factors for colic identified in some of these studies. This is not a systematic or comprehensive review of the epidemiology of colic, which is a large subject area, and we acknowledge that there may be personal and cultural bias in the papers we have selected to review. Instead this is an opinionated review that highlights those

* Corresponding author. Tel.: +44 151 795 6011; fax: +44 151 794 6005.

E-mail address: darcher@liverpool.ac.uk (D.C. Archer).

areas that we consider to be most relevant to the practitioner.

Many papers report odds ratios from observational studies. An odds ratio (OR) is defined as the odds of disease in exposed individuals relative to the odds of disease in the unexposed (Schlesselman, 1982). An OR of 1 suggests that there is no association between exposure (e.g., feed type) and disease (i.e., colic), OR < 1 suggests that exposure reduces the risk of colic and OR > 1 suggests that exposure increases the risk of colic.

2. Incidence, types of colic and mortality rates

The reported incidence of colic in different horse populations varies from 3.5 to 10.6 colic episodes per 100 horses per year (Kaneene et al., 1997; Tinker et al., 1997b; Traub-Dargatz et al., 2001; Hillyer et al., 2001). Within a horse population, incidence rates can vary considerably, influenced by variables between and within horse establishments. Tinker et al. (1997b) reported between-farm variations from 0 to 30 episodes per 100 horse years. It has been suggested that investigations should be undertaken in horse populations with more than 20 colic episodes per 100 horse years to identify preventative measures that could be undertaken (White, 1997).

In many cases of colic, the exact gastrointestinal dysfunction or lesion is unknown. A diagnosis of spasmodic/gas colic or colic of unknown cause was diagnosed in 69–72% of cases seen within the general equine population and only 7–9% of cases in two of these studies were surgical in nature (Proudman, 1991; Hudson et al., 2001; Mair, 2004). Risk factors may be different for specific types of colic and studies looking at colic of any cause could miss some disease specific findings (Reeves et al., 1996; Hudson et al., 2001). However, it is important to note that these specific types of colic represent only a small minority of horses and most cases of colic within the general equine population fall into the 'spasmodic/gas/unknown' category.

Overall, reports of estimated case fatality rates as a result of colic vary from 6.7% to 15.6% depending on the population studied and the type of lesion (Tinker et al., 1997b; Kaneene et al., 1997; Mair, 2004). In one study, medical colics were reported to have a case fatality rate of 9% compared to 31% in horses with surgical lesions (Kaneene et al., 1997) highlighting the importance of preventing colic, particularly those forms that may require surgical intervention. Acute and subacute forms of equine grass sickness (EGS) are invariably fatal making prevention of this disease a key area of current equine gastrointestinal research in the UK.

2.1. Geography

Traub-Dargatz et al. (2001) did not identify any association between incidence of colic and geographic location in the USA. However, it must be emphasised that data were derived from a national equine survey that was conducted over a limited time period only (Spring 1998–Spring 1999). It is recognised that horses living in or originating from a particular geographic area are at increased risk for developing specific types of colic (White, 1997). One example is EGS which occurs predominantly in the UK, Northern Mainland Europe and South America (McCarthy et al., 2001). Other examples of types of colic that exhibit geographical clustering include sand colic, which is common in regions with sandy soils, and enterolithiasis (Ragle et al., 1989; Hassel et al., 1999).

Obstruction of the gastrointestinal tract by enteroliths is uncommonly seen in the UK but is particularly common in certain geographical regions such as California, USA. Reasons for clustering of this disease may include mineral content of soil, feed and water in individual regions but, given that all horses within these regions are not affected, it is likely that the disease is multi-factorial in nature (Hassel et al., 1999). The prevalence and severity of duodenitis-proximal jejunitis (also known as proximal or anterior enteritis) is reported to vary depending on geographic location. California would appear to have a lower prevalence of the condition than other regions of the USA and Europe. A more severe form of this condition has been reported in Southeastern USA compared to Northeastern regions of the country and generally the less severe form of the condition is reported in the UK (Edwards, 2000; Freeman, 2000).

2.2. Season

The incidence of colic may be seasonal in some horse populations and for specific types of colic. Proudman (1991) reported an increased incidence of colic of any type during the months of spring and autumn in the UK. This pattern of colic incidence was also reported in Thoroughbred horses in training yards in the UK (Hillyer et al., 2001).

In two separate studies conducted over a 12 month period in the USA, Traub-Dargatz et al. (2001) reported a higher percentage of colic cases in spring compared to summer or autumn, whereas Tinker et al. (1997a,b) reported highest incidence density in the months of December, March and August of the study year. EGS can occur at any time of the year but peak incidence of this condition in the UK is reported in the months of spring and early summer and the month of May in particular (Doxey et al., 1991; Wood et al., 1998). In addition there is strong evidence that, in the UK, grass

sickness exhibits space-time clustering particularly within 5 km and 20 days of an arbitrary case (French et al., 2002).

Over a 10 year period, in one referral horse population in the UK, epiploic foramen entrapment of the small intestine (EFE) was consistently more prevalent in the months of December, January and February (Archer et al., 2004b). Despite many suggestions that weather-related factors may be associated with the development of colic, there is no statistical proof of this and the precise conditions predisposing to colic remain ill defined (Cohen, 1997; Goncalves et al., 2002; McCarthy et al., 2001). It is important to consider that seasonal incidence of colic may not be associated with weather factors alone but other potentially alterable management factors common to that time of the year such as stabling, quantities of feed or exercise levels (Hillyer et al., 2001; Archer et al., 2004b).

3. Horse-level risk factors

A variety of horse-level factors may put an individual at increased or decreased risk of suffering from colic. Measures to limit exposure to such risk factors are difficult to conceive, but knowledge of these factors can assist in the diagnosis of certain types of colic. Horse owners or carers may also be more likely to observe for signs of colic, identifying the disease at an earlier stage, in individuals known to be at significantly increased risk of developing colic.

3.1. Signalment

Some types of colic may be gender-specific in nature (e.g., inguinal herniation in stallions, and uterine torsions in mares) but overall there is no clear association between gender and colic. Whereas some studies have reported geldings to be at increased risk of suffering colic associated with pedunculated lipomas (Blickslager et al., 1992; Edwards and Proudman, 1994), others have reported geldings to be at reduced risk of developing colic of any cause (Kaneene et al., 1997) or have found no significant association between gender and incidence of colic (Reeves et al., 1989, 1996; Tinker et al., 1997a; Cohen et al., 1999; Traub-Dargatz et al., 2001). Associations between gender and risk of colic may be confounded by other factors such as use of horse and associated management practices. Foaling (Kaneene et al., 1997) or the 60–150 day period after foaling (White, 1997) has been associated with increased risk of colic in mares.

Studies investigating the association between age of the horse and colic have also yielded conflicting results. Foals <6 months old were found to be at decreased risk of suffering from colic in one study (Traub-

Dargatz et al., 2001) but certain types of colic such as surgical lesions of the small colon (Reeves et al., 1989), intussusceptions (Cohen, 1997) and ascarid impactions (Southwood et al., 2002) are reportedly more prevalent in this age group. Horses between 2–10 years old were reported to be at increased risk in another study (Tinker et al., 1997b) but the authors noted that there may have been other confounding factors to explain this or the age group may have been a marker for use of horse, training, exercise or nutritional factors. Conversely, in other studies, horses >8 years (Cohen and Peloso, 1996), 10 years (Cohen et al., 1999) or horses of increasing age (Reeves et al., 1989; Kaneene et al., 1997) were found to be at increased risk of suffering colic.

Although the previously held belief that older horses were more likely to suffer from EFE has been refuted (Freeman and Schaeffer, 2001), older horses and ponies are at increased risk of suffering from colic associated with pedunculated lipomas (Blickslager et al., 1992; Edwards and Proudman, 1994). Young horses have been shown to be at increased risk of EGS in a number of studies (Gilmour and Jolly, 1974; Doxey et al., 1991) and horses aged 3–5 years old (Wood et al., 1998) or 4–5 years (McCarthy et al., 2004b) are reported to be at maximal risk.

The association between breed of horse and colic varies between studies. Thoroughbreds were more likely to develop colic in studies by Traub-Dargatz et al. (2001) and Tinker et al. (1997a). The latter study also identified Arab horses to be at reduced risk of colic whereas other studies (Cohen et al., 1995, 1999; Cohen and Peloso, 1996; Reeves et al., 1996) found Arab horses to be at significantly increased risk. Some studies have identified no association between breed and colic (Kaneene et al., 1997). It is important to consider other factors that may explain these findings. For example breed may be confounded by use and related management practices or, in hospital based studies, there may be bias in the breeds referred to clinics for colic. Specific types of colic are seen more frequently in certain types or breeds of horses such as dorsal colon displacement in large Warmblood breeds (White, 1997) or small colon impactions in ponies, Arab and American miniature horses (Dart et al., 1992). Enterolithiasis is particularly prevalent in certain breeds such as Arab horses and Morgans making a genetic predisposition to the disease possible (Cohen et al., 2000; Hassle, 2004).

3.2. Crib-biting/windsucking behaviour

Horses exhibiting crib-biting/windsucking behaviour have been identified to be at significantly increased risk of suffering from simple colonic obstruction and distension (SCOD) colic (OR 70.0, 95%CI 9.59–510.96) (Hillyer et al., 2002) and EFE in two hospital populations

(Illinois OR 34.7, 95%CI 6.2–194.6 and Liverpool OR 8.2, 95%CI 4.5–15.1) (Archer et al., 2004a). Crib-biting or windsucking behaviour may not play a direct role in the aetiology of these types of colic but may be a marker for management practices, temperament or other factors that predispose to colic. An epidemiological contribution to the gastric ulceration story was made by Nicol et al. (2002) who reported an intervention study performed in foals showing crib-biting behaviour. The addition of an antacid supplement to the diet of some foals resulted in decreased crib-biting behaviour and improvement in the severity of gastric ulceration.

3.3. History of previous colic

Horses with a history of colic have been identified to be at increased risk of suffering further episodes (Cohen et al., 1995, 1999; Reeves et al., 1996; Tinker et al., 1997b). In a study by Traub-Dargatz et al. (2001), 43.5% of horses suffering from colic were reported to have had colic previously, 11% of these within 1 year of the colic event. Horses previously suffering colic have also been significantly associated with SCOD colic (Hillyer et al., 2002).

Histological studies of the intestinal nervous system of horses undergoing surgery for large colon disorders have identified reduced density of interstitial cells of Cajal (Fintle et al., 2004). This is further evidence to support the hypothesis that a sub-population of horses exists with abnormal intestinal physiology that predisposes them to recurrent colic episodes. Individuals with a history of recurrent colic and previous identification of enteroliths in the faeces are indicators that an individual may be at increased risk of suffering an obstruction due to enterolithiasis and are candidates for implementation of preventative measures (Hassel et al., 1999). Horses that have previously undergone surgery for colic are at significantly increased risk of further colic episodes (Cohen et al., 1995, 1999; Cohen and Peloso, 1996). Surgical or therapeutic methods to prevent ileus, minimise the formation of adhesions or prevent recurrence of specific types of colic following surgery are ways in which future episodes of colic may be prevented; these are outwith the scope of this paper and will not be reviewed.

4. Parasites

4.1. The role of parasites and colic

Parasites are a well-documented cause of colic in the horse. Motility disturbances, arteritis, thromboembolism and peritonitis caused by migrating larvae of *Strongylus vulgaris* were once thought to cause up to 90% of all colic episodes in the horse (White, 1997).

The availability of modern anthelmintics has resulted in reports of *S. vulgaris*-associated colic now being rare.

More recently, the tapeworm *Anoplocephala perfoliata* has been implicated as a cause of colic. Proudman et al. (1998) demonstrated a strong association between intensity of infection with *A. perfoliata* and ileal impaction and spasmodic colic, and this finding has been supported by a further epidemiological study (Little and Blikslager, 2002). The development of a serological assay to quantify the level of infection by *A. perfoliata* has improved detection of these parasites (Proudman and Trees, 1999; Proudman and Holdstock, 2000).

Uhlinger (1990) reported that a high proportion of colics in one population of horses were likely to have been a result of cyathostominae due to the fact that the incidence of colic was significantly reduced by anthelmintic schedules designed to control these particular parasites. This study confirms the protective effects of intervention strategies to decrease intestinal parasite burden. Caecocaecal and caecocolic intussusceptions have been reported to have clinical and/or pathological evidence of concurrent larval cyathostomiasis (Mair et al., 2000), and the intestinal phase of ascarids can be associated with intestinal obstruction, rupture, peritonitis, intussusception or abscessation in foals; these cases usually have a grave prognosis (Southwood et al., 2002).

4.2. Administration of anthelmintics

Despite the availability and frequent use of anthelmintic drugs, parasitic infections are still common in horses. In a study performed in the UK, 69.5% of horses screened were infected with parasites. Of these horses, 30% were infected solely by strongyles, 32% only with tapeworms and 38% had mixed infections (Barrett et al., 2004). However studies relating parasite infestation and anthelmintic control with colic have yielded conflicting results.

Some studies have identified either no association of colic with the type of anthelmintic administered or the parasite control programme (Cohen et al., 1995; Hillyer et al., 2001; Traub-Dargatz et al., 2001), increased risk if horses were not on a regular de-worming programme (Cohen et al., 1999) or a decreased risk of colic associated with worming (Uhlinger, 1990; Reeves et al., 1996), particularly within 14 days after administration (Hudson et al., 2001). Failure to administer a pyrantel salt in the three months prior to admission was a risk factor for development of ileal impaction in one study (Little and Blikslager, 2002), supporting the role of *A. perfoliata* in the aetiology of this specific type of colic. Absence of administration of moxidectin/ivermectin anthelmintic in the previous 12 months was associated

with SCOD in another study (Hillyer et al., 2002); the precise reason for this was unclear.

Some studies have identified increased risk of colic associated with anthelmintic administration although it is possible that this is associated with better management practices including closer observation for colic (Kaneene et al., 1997). Cohen et al. (1999) reported increased risk of colic in the seven day period following anthelmintic administration. This phenomenon has been investigated by Barrett et al. (2005) who found serological evidence of large tapeworm burdens in horses suffering from post-dosing colic. The authors suggested that colic was caused by the sudden and rapid death of existing tapeworms and it has been suggested that this situation might be avoided by preventing large burdens becoming established.

The relationship between frequency of anthelmintic administration (Wood et al., 1998) or administration of ivermectin on the ultimate and penultimate treatments (McCarthy et al., 2004a) and the development of EGS is unclear and requires further investigation. Recent administration of an anthelmintic has been identified as a risk factor for larval cyathostomiasis (Reid et al., 1995). Anthelmintics may also result in colic due to intestinal obstruction as a result of rapid death of intraluminal ascarids in younger horses (Southwood et al., 2002). Strategies to minimise infection intensity of these parasites would therefore seem prudent. Current evidence suggests that a properly implemented, appropriate, parasite control programme should decrease the incidence of gastro-intestinal disorders among horses but, although parasite control probably reduces the risk of colic, many other sufficient causes of colic also exist (Cohen et al., 1999).

4.3. Other strategies to reduce parasite burden

In many management systems, parasite control depends primarily on frequent administration of anthelmintic drugs and under these conditions it is important to administer these frequently enough to maximise the animals health status. Anthelmintic schedules designed to minimise faecal egg counts may be expected to reduce the risk of colic but other policies such as strategic treatments may be expected to do the same thing (Uhlinger, 1990).

Drug resistance in cyathostominae (small strongyles) has emerged as an impediment to effective parasite control in the horse. Although moxidectin and fenbendazole have been shown to be effective against the encysted larval stages of the parasites, drug resistance is reported to all classes of drugs except the macrocyclic lactones (ivermectin and moxidectin) and is a limiting factor in the control of these parasites (Lyons et al., 2000). It is also recognised that in any group of horses there are always individuals that are more prone to parasitic infections

(Barrett et al., 2004). Therefore it is important for horse owners to consider other ways in which the parasite populations on the pasture can be reduced including rotation or co-grazing with ruminants, removal of faeces from pastures and composting of stable manure and bedding before spreading it on pastures (Lyons et al., 2000).

5. Feed types and feeding practices

Certain feed types and feeding practices have long been identified as a cause of colic, Gamgee (1857) stating “too much hay and an excessive quantity of corn may induce violent indigestion and gripes...new hay and new oats combined are proverbially known to be injurious”. Diets with an imbalance of roughage to concentrate, feeding certain feedstuffs such as coastal Bermuda grass hay, spoiled feed, young protein-rich grass, coarse poor quality roughage, pelleted feeds, over-feeding, underfeeding and feeding on the ground have also previously been implicated but these findings were anecdotal or based on observations of case populations without any comparable control population (Tinker et al., 1997b).

5.1. Forage

Traub-Dargatz et al. (2001) reported no association of colic with types of dried forage or frequency of feeding forage. In contrast horses with a history of being fed coastal grass hay were significantly associated with previous colic and recurrent colic in one study (Cohen and Peloso, 1996), whereas Hudson et al. (2001) reported feeding hay from round bales and hay other than alfalfa, coastal or Bermuda types to be significantly associated with colic. These findings were thought to have been related to poor quality of hay or the presence of mould, making hay less digestible, or to the percentage of fibre and protein; the types of hay associated with increased risk were of high fibre and low protein content and hence may have been less digestible, predisposing horses to colic (Cohen et al., 1999; Hudson et al., 2001). The latter finding may be surprising given that the equine gastrointestinal tract is adapted to a very high fibre diet.

Tinker et al. (1997b) reported decreased risk of colic in horses with less easily digested, more complex or varied diets with a high proportion of forage in the form of either hay or pasture. There is a need for investigation into the relationship of specific nutrients such as fibre, and measurements of these in feeds, in relation to colic (White, 1997). Feeding of coastal Bermuda grass hay in the USA has been associated with the development of ileal impactions; a reduced risk was identified in horses, in high-risk areas, given

pelleted feed in addition to forage (Little and Blikslager, 2002). In Texas, USA, horses with enterolithiasis were demonstrated to be at increased risk if fed alfalfa hay (Cohen et al., 2000).

5.2. Concentrates

Two studies reported no association between colic and feeding a particular type of concentrate (Cohen et al., 1999; Traub-Dargatz et al., 2001) whereas feeding of >2.7 kg oats/day was significantly associated with colic in another study (Hudson et al., 2001). Tinker et al. (1997b) found higher concentrate intakes to be associated with the highest risk of colic, this risk increasing 6-fold in horses being fed the greatest quantities of concentrate (>5 kg/day) compared to horses on pasture receiving no concentrates. In this study, feeding whole grain decreased the risk of colic and feeding of more processed feeds such as pellets or sweet feeds increased the risk. In comparison, colic risk was increased in horses fed whole-grain corn but when all non-roughage concentrate feeds were combined, colic risk was found to decrease with increased intake of concentrates (Reeves et al., 1996). However this association was considered more likely to be a result of confounding by physical exercise, which could not be controlled for in their analysis.

Concentrate type, quantity and frequency of feeding do appear to be important in the aetiopathogenesis of colic and require further investigation. Equine Gastric Ulcer Syndrome (EGUS) can cause overt signs of colic (Vatistas et al., 1999b) and a number of dietary risk factors, including the feeding of a high concentrate diet, have been implicated as risk-factors for this condition (Buchanan and Andrews, 2003).

5.3. Feeding practices

Intermittent feeding has been used as a model to consistently produce EGUS (Murray, 1994) and in a separate study ulcers developed when feed was withheld (Vatistas et al., 1999a). The greater severity and prevalence of gastric ulceration in stall confined horses, compared to those turned out to pasture, was considered to be a result of altered eating behaviour in the former (Murray and Eichorn, 1996). Hudson et al. (2001) identified feeding a new batch of hay in the preceding two weeks to be most strongly associated with increased risk of colic (OR 4.9, 95%CI 2.1–11.4). Increased risk following a change in hay was also significantly associated with colic in another study (Cohen et al., 1999).

An increased risk of colic was reported in horses with more than the expected one change/year of hay (Tinker et al., 1997b) and a recent change in type or amount of grain or concentrate fed was also signifi-

cantly associated with increased risk (Tinker et al., 1997b; Hudson et al., 2001). Diet change in the two week period prior to examination was significantly associated with colic in general (Cohen et al., 1995, 1999) and increased risk of SCOD colic was associated with increased concentrate feeding in the 14 days after change (Hillyer et al., 2002). Change in feed type or quality in the previous 14 days was also found to be associated with increased risk of EGS in a study by McCarthy et al. (2004a). These studies demonstrate that change in feeding practices is significantly associated with increased risk of colic, supporting historical belief that change to new types or amounts of feed should be gradual.

5.4. Dietary modifications to prevent specific types of colic

Knowledge of dietary risk factors can be used to formulate strategies to prevent particular types of colic from developing or recurring. Nadeau et al. (2000) found that the number and severity of gastric ulcers was significantly lower in horses fed alfalfa-grain diets compared to those receiving bromegrass hay. In conjunction with pharmacologic therapy (Andrews et al., 1999) pasture turnout has been advocated as the best dietary method of treating and preventing recurrence of EGUS. Provision of continual supplies of good quality grass or alfalfa hay, minimising feeding of concentrates and substitution of barley or oats are recommended in horses that must be kept stabled (Buchanan and Andrews, 2003). The feeding of preserved forage (hay or haylage) to horses at high risk of developing EGS may be protective (McCarthy et al., 2004a) although Wood et al. (1998) reported no evidence that the feeding of hay and/or forage was associated with decreased risk.

Recurrence of enterolithiasis in 7.7% of previously affected horses (Hassel et al., 1999) makes implementation of preventative strategies important. Current recommendations for horses at high risk include elimination of alfalfa from the diet, grass hay supplementation, daily feeding of concentrates, daily exercise with access to pasture grass and apple cider vinegar supplementation to promote colonic acidification (Hassel, 2004).

Accumulation of sand in the large colon may result in obstruction and possible torsion of the large colon, although the exact quantity of sand that needs to accumulate to cause colic and an individual's tolerance to sand may vary (Bertone et al., 1988; Ragle et al., 1989). The use of psyllium mucilloid to encourage expulsion of sand from the large intestine has been advocated (Bertone et al., 1988) but was shown in one study to have no effect on sand evacuation from the large intestine (Hammock et al., 1998). In the latter study a reduction of intra-colonic sand was seen when

sand intake was prevented. Preventative measures involve not feeding horses off the ground, limiting access to sandy yards and paddocks and the feeding of a high-bulk diet.

6. Other management factors

6.1. Exercise

Cohen et al. (1999) reported an increased risk of colic in horses being exercised at least once a week compared to those turned out with no ridden exercise (OR 1.6, 95%CI 1.2–2.2). Hillyer et al. (2001) suggested that the incidence of colic may have been associated with stage of training or level of activity in horses on National Hunt or Flat racing premises based on the seasonal pattern of colic in these two groups. However, this study did not control for factors such as nutrition, transport and use, which confound the relationship between exercise and colic. SCOD was also associated with a recent change in a regular exercise programme, particularly in the week following change (Hillyer et al., 2002). This effect remained significant when feeding and housing practices were taken into account in the final multivariable model.

Since Hammond et al. (1986) first reported a high prevalence (66%) of gastric ulcers in a population of Thoroughbred racehorses in Hong Kong, many researchers have documented the prevalence of EGUS in other groups of horses, primarily in North America, including Thoroughbred and Standardbred racehorses and horses used for endurance riding or showing (Murray, 1989; Murray et al., 1996; Vatistas et al., 1999b; McClure et al., 1999; Rabuffo et al., 2002; Begg and O'Sullivan, 2003; Nieto et al., 2004). The prevalence of EGUS in some of these studies has been as high as 93% (Murray et al., 1996; Vatistas et al., 1999b). In one study of Standardbred racehorses actively racing horses were more likely to have gastric ulceration than those being rested (Dionne et al., 2003). Simulated race-training has been used as a model to induce and maintain gastric ulceration supporting the role of intense exercise in the development of this condition (Vatistas et al., 1999a).

It has been hypothesised that development or worsening of squamous lesions when horses are in intensive training is due to increased intra-abdominal pressure and subsequent gastric compression pushing acidic contents into the squamous lined portion of the stomach. In addition the duration of acid exposure may be directly related to daily duration of exercise (Lorenzo-Figueras and Merritt, 2002). Knowledge of the high prevalence and recurrence rates of EGUS in these populations is important and, although there is limited opportunity to modify the management of

horses in race training, dietary changes and pharmacologic therapy may be instituted (Buchanan and Andrews, 2003).

6.2. Stabling and access to pasture

Horses that spend 100% of their time in the stable have been reported to be at increased risk of colic when compared to horses that spent no time in a stable (Hudson et al., 2001). However, mild episodes of colic may be more likely to be detected in stabled horses compared to those turned out at pasture for long periods of time (Kaneene et al., 1997) and stabled horses may experience other management factors that predispose to colic. In addition, horses that are predominantly stabled may have less opportunity for exercise. Cohen et al. (1995, 1999) identified a change in stabling within the previous two weeks to be associated with increased risk of colic, although these studies did not examine which particular stabling changes predisposed horses to colic.

Increased number of hours spent in the stable was also associated with increased risk of SCOD, particularly in the 14 days following change in housing, and a large increase in risk (OR 7.58 95%CI 2.46–23.34) was found in horses stabled between 19 and 24 h per day (Hillyer et al., 2002). Owners should be aware of these factors particularly when horses that are usually turned out for significant periods of the day are confined to the stable. In these situations owners should be advised to monitor levels of feed intake and faecal output enabling early recognition of colic problems.

Decreased exposure to pasture, either a decrease in acreage or time at pasture, was a significant risk-factor for colic in one study (Hudson et al., 2001). Traub-Dargatz et al. (2001) reported no association between colic and type of pasture, pasture quality, percentage of pasture with edible vegetation or stocking density. In another study, stocking density of <0.5 horses/acre was associated with significantly increased risk of colic (Cohen and Peloso, 1996). Further investigations are required to define what types of pasture exposures and management predispose to colic (Reeves et al., 1996).

Access to pasture and duration of access have been associated with increased risk of EGS (Gilmour and Jolly, 1974) and in one study more than 95% of EGS cases had access to grazing (Wood et al., 1998). For many years EGS has been associated with horses grazing certain pastures and increased risk of disease has been identified in horses that have changed pasture in the preceding two weeks (Wood et al., 1998; McCarthy et al., 2001). McCarthy et al. (2004b) identified an association between EGS and increased soil nitrogen content, pasture disturbance and previous occurrence of EGS on the premises. In a separate study recurrence of EGS was associated with loam and sand soils and

mechanical removal of droppings whereas chalk soil, co-grazing of ruminants, grass cutting on pastures and removal of droppings by hand was associated with reduced recurrence (Newton et al., 2004). Based on these two studies, current best advice is that young horses should avoid grazing pastures associated with previous EGS cases and that pasture disturbance and excavation should be avoided. In addition good pasture management, co-grazing of ruminants and avoidance of pasture sweepers may potentially reduce recurrence of EGS.

6.3. Access to water

Horses with access to ponds have been shown to be at decreased risk of suffering colic (Cohen et al., 1995). This is in agreement with the findings of Kaneene et al. (1997) where provision of water to groups of horses from sources other than buckets, troughs or tanks was associated with decreased risk. Hudson et al. (2001) found no significant association between the type of watering practice and colic but none of the horses in their study had access to water denied for longer than 4 h. An increased risk of colic was identified in another study in horses without access to water in outdoor enclosures (Reeves et al., 1996).

Water deprivation may be associated with increased risk of large colon impactions (White, 1997) and could partially explain the large increase in risk of horses suffering SCOD following transportation (Hillyer et al., 2002). In summary, provision of fresh palatable water is critical in prevention of colic in the horse and, although this may appear obvious, owners should be made aware of the importance of providing continual access to fresh water and regularly cleaning water sources (Cohen, 2003). Evaluation of mineral components of the water supply may be recommended in horses suffering from enterolithiasis (Hassle, 2004).

6.4. Transport

The association between colic and transport is inconsistent; Cohen et al. (1995) did not find any association whereas White (1997) reported increased risk of colic following transport. Transportation has also been implicated as a risk factor for EGUS (Buchanan and Andrews, 2003). Hillyer et al. (2002) reported that transport in the previous 24 h was associated with a large increase in risk for SCOD (OR 17.48 95%CI 2.16–141.35). This finding may be related to transport itself or may be confounded by simultaneous management changes such as change in premises, physical constraint and deprivation of water and feed. Owners of horses undergoing transport should be aware of these factors and measures taken to minimise such changes e.g., ensuring that horses are regularly offered water.

6.5. Dental prophylaxis

Cohen et al. (1995) did not identify frequency of dental prophylaxis to be associated with decreased risk of colic although both cases (horses with colic) and their controls received dental care making this comparison difficult. Poor dentition is reported to increase the risk of large colon impaction (White, 1997). This is supported by Hillyer et al. (2002) who identified horses that had their teeth checked or treated fewer times per year to be associated with increased risk of SCOD. Owners should be aware of the importance of regular dental examination in the prevention of colic.

6.6. Vaccination

Tinker et al. (1997b), in the USA, identified an increased risk of colic following Potomac horse fever vaccination particularly up to 14 days following vaccination. This association of colic with vaccination has not been found in other studies and merits further investigation to determine if there is a true, increased risk of colic associated with use of this vaccination or if vaccination is a marker for the type of management and health care that the horse receives.

The possibility that EGS may be prevented by vaccination has received renewed interest. A vaccine trial with an antitoxin neutralised botulinum toxin was conducted by Tocher et al. in 1923 and, although there was a significant reduction in mortality following vaccination, the “*B. botulinus* theory” was discounted a few years later (reviewed by McCarthy et al., 2001). It is now hypothesised that EGS results from a *Clostridium botulinum* type C toxicoinfection, due to the strong association between the toxin found in the gastrointestinal tract of horses with the disease (Hunter et al., 1999). Several of the risk factors identified by Newton et al. (2004) may directly or indirectly relate to soil disturbance and consequent soil contamination by grass increasing the rate of exposure of grazing horses to *C. botulinum* which resides in soil. The *C. botulinum* theory has been further supported by the findings of McCarthy et al. (2004a) where EGS was significantly associated with low antibody levels to three clostridial antigens. In future, EGS may potentially be prevented by vaccinating horses, thereby increasing the systemic level of anti-clostridial antibodies; this is an area of current research (Hedderon and Newton, 2004).

6.7. Premises/owner factors and use of horse

Horses whose owners provide their care have been shown to be at decreased risk of colic or recurrence of colic compared to horses cared for by a non-owner (Reeves et al., 1996; Hillyer et al., 2001). Owners may provide better health care for their horses or this finding

may be related to other factors such as density of horses on the premises or their exercise level (Cohen, 2003). Traub-Dargatz et al. (2001) reported no association between the gender of person making health care decisions on the operation or the relationship of the person implementing health care to the owner of the operation. The latter study, and a study by Reeves et al. (1996) also did not find any association between colic and use of the horse.

Horses used for eventing, showing, or horses in training, particularly flat-trained racehorses, have been shown to be at increased risk in some studies (Kaneene et al., 1997; Tinker et al., 1997a; Hillyer et al., 2001). However, in these studies confounding factors such as age, breed and type of horse, nutrition, exercise and transport were not all taken into account when considering use of horse as a risk-factor for colic. Use of horse may be significant when specific types of colic are considered e.g., strangulating obstructions of the large colon in brood mares (Reeves et al., 1996). Mild episodes of colic may also be missed on premises where horses spend most of their time at pasture and are not used for any activities (Kaneene et al., 1997).

In addition to recent change of pasture, recent change of premises is associated with increased risk of EGS (Gilmour and Jolly, 1974; Doxey et al., 1991). Horses on premises where EGS has previously occurred are also at increased risk (Wood et al., 1998; McCarthy et al., 2004b). Newton et al. (2004) reported that recurrence of EGS was associated with establishments with larger numbers of horses, the presence of younger animals, stud farms and livery/riding establishments and rearing of domestic birds. Some of these findings may be explained by age and pasture associated risk-factors whereas others, such as rearing of domestic birds, require further investigation.

7. Conclusions

Several risk factors for colic have long been recognised: “the effects of water are but transitory and insignificant unless in co-operation with other agents, such as an improper quantity of deteriorated food, or overfeeding of an animal whose vital powers have been exhausted by overwork...farmers cannot understand why they should be so much troubled with this disease; but wherever I have been, much of it has existed...” (Gamgee, 1857). Epidemiological studies have illustrated the role that management-level and horse-level factors play in the development of colic and have identified previously unknown risk-factors. The significance of individual risk-factors varies between studies. This may be explained by the variation in numbers and geographical locations of the populations, including selection of cases and controls, and

even the definition of colic used (Reeves, 1997; Gonçalves et al., 2002).

Given that the equine gastrointestinal tract evolved to cope with trickle-feeding it is perhaps not surprising to discover the role that current management practices play. Horse owners should be made aware of the significance of these practices, particularly in horses affected by colic, and advised of measures that may be implemented to prevent recurrence. Further research is required to more precisely define the role of factors such as nutrition and exercise in this disease and the effect of preventative measures.

Acknowledgement

Debra Archer's Research Training Scholarship is funded by the Horserace Betting Levy Board.

References

- Andrews, F., Bernard, W., Byars, D., Cohen, N., Divers, T., MacAllister, C., 1999. Recommendations for the diagnosis and treatment of equine gastric ulcer syndrome (EGUS). *Equine Veterinary Education* 11, 122–134.
- Archer, D.C., Freeman, D.E., Doyle, A.J., Proudman, C.J., Edwards, G.B., 2004a. Association between cribbing and entrapment of the small intestine in the epiploic foramen in horses: 68 cases (1991–2001). *Journal of the American Veterinary Medical Association* 15, 562–564.
- Archer, D.C., Proudman, C.J., Pinchbeck, G., Smith, J.E., Edwards, G.B., 2004b. Entrapment of the small intestine in the epiploic foramen in the horse: retrospective analysis of 71 cases (1991–2001). *Veterinary Record* 155, 793–797.
- Barrett, E.J., Farlam, J., Proudman, C.J., 2004. Field trial of the efficacy of a combination of ivermectin and praziquantel in horses infected with roundworms and tapeworms. *Veterinary Record* 154, 323–325.
- Barrett, E.J., Blair, C.W., Farlam, J., Proudman, C.J., 2005. Post-dosing colic and diarrhoea in horses with serological evidence of tapeworm infection. *Veterinary Record* 156, 252–253.
- Begg, L.M., O'Sullivan, C.B., 2003. The prevalence and distribution of gastric ulceration in 345 racehorses. *Australian Veterinary Journal* 81, 199–201.
- Bertone, J.J., Traub-Dargatz, J.L., Wrigley, R.W., Bennett, D.G., Williams, R.J., 1988. Diarrhoea associated with sand in the gastrointestinal tract of horses. *Journal of the American Veterinary Medical Association* 193, 1409–1412.
- Blickslager, A.T., Bowman, K.F., Haven, M.L., Tate, L.P., Bristol, D.G., 1992. Pedunculated lipomas as a cause of intestinal obstruction in horses: 17 cases (1983–1990). *Journal of the American Veterinary Medical Association* 201, 1249–1252.
- Buchanan, B.R., Andrews, F.M., 2003. Treatment and prevention of equine gastric ulcer syndrome. *Veterinary Clinics of North America Equine Practice* 19, 575–597.
- Cohen, N.D., 1997. Epidemiology of colic. *Veterinary Clinics of North America Equine Practice* 13, 191–201.
- Cohen, N.D., 2003. The John Hickman Memorial Lecture: colic by numbers. *Equine Veterinary Journal* 35, 343–349.
- Cohen, N.D., Peloso, J.G., 1996. Risk factors for history of previous colic and for chronic, intermittent colic in a population of horses.

- Journal of the American Veterinary Medical Association 208, 697–703.
- Cohen, N.D., Matejka, P.L., Honnas, C.M., Hooper, R.N., 1995. Case-control study of the association between various management factors and development of colic in horses. Texas Equine Colic Study Group. *Journal of the American Veterinary Medical Association* 206, 667–673.
- Cohen, N.D., Gibbs, P.G., Woods, A.M., 1999. Dietary and other management factors associated with colic in horses. *Journal of the American Veterinary Medical Association* 215, 53–60.
- Cohen, N.D., Vontur, C.A., Rakestraw, P.C., 2000. Risk factors for enterolithiasis among horses in Texas. *Journal of the American Veterinary Medical Association* 216, 1787–1794.
- Dart, A.J., Snyder, J.R., Pascoe, J.R., Farver, T.B., Galuppo, L.D., 1992. Abnormal conditions of the equine descending (small) colon: 102 cases (1979–1989). *Journal of the American Veterinary Medical Association* 200, 971–978.
- Dionne, R.M., Vrins, A., Doucet, M.Y., Pare, J., 2003. Gastric ulcers in Standardbred racehorses: prevalence, lesion description and risk factors. *Journal of Veterinary Internal Medicine* 17, 218–222.
- Doxey, D.L., Gilmour, J.S., Milne, E., 1991. A comparative study of normal equine populations and those with grass sickness (dysautonomia) in eastern Scotland. *Equine Veterinary Journal* 23, 365–369.
- Edwards, G.B., 2000. Duodenitis-proximal jejunitis (anterior enteritis) as a surgical problem. *Equine Veterinary Education* 12, 318–321.
- Edwards, G.B., Proudman, C.J., 1994. An analysis of 75 cases of intestinal obstruction caused by pedunculated lipomas. *Equine Veterinary Journal* 26, 18–21.
- Fintle, C., Hudson, N.P.H., Mayhew, I.G., Edwards, G.B., Proudman, C.J., Pearson, G.T., 2004. Interstitial cells of Cajal (ICC) in equine colic: an immunohistochemical study of horses with obstructive disorders of the small and large intestines. *Equine Veterinary Journal* 36, 474–479.
- Freeman, D.E., 2000. Duodenitis-proximal jejunitis. *Equine Veterinary Education* 12, 322–332.
- Freeman, D.E., Schaeffer, D.J., 2001. Age distributions of horses with strangulation of the small intestine by lipoma of in the epiploic foramen: 46 cases (1994–2000). *Journal of the American Veterinary Medical Association* 219, 87–89.
- French, N.P., McCarthy, H., Edwards, G.B., Proudman, C.J., 2002. The use of space-time K function analysis to detect and describe clustering of equine grass sickness cases in the UK. In: *Proceedings of the Seventh International Equine Colic Research Symposium*, p. 75.
- Gamgee, J., 1857. On colic or indigestion of the horse. *The Highland Societies Transactions for July and October 1857*, Edinburgh.
- Gilmour, J.S., Jolly, G.M., 1974. Some aspects of the epidemiology of equine grass sickness. *Veterinary Record* 95, 77–81.
- Goncalves, S., Julliand, V., Leblonde, A., 2002. Risk factors associated with colic in horses. *Veterinary Research* 33, 641–652.
- Hammock, P.D., Freeman, D.E., Baker, G.J., 1998. Failure of psyllium mucilloid to hasten evacuation of sand from the equine large intestine. *Veterinary Surgery* 27, 547–554.
- Hammond, C.J., Mason, D.K., Watkins, K.L., 1986. Gastric ulceration in mature Thoroughbred horses. *Equine Veterinary Journal* 18, 284–287.
- Hassel, D.M., Langer, D.L., Snyder, J.R., Drake, C.M., Goodell, M.L., Wyle, A., 1999. Evaluation of enterolithiasis in equids: 900 cases (1973–1996). *Journal of the American Veterinary Medical Association* 15, 233–237.
- Hassel, D.M., 2004. Update on enterolithiasis. In: *Proceedings of the American College of Veterinary Surgeons veterinary symposium*, Denver, Colorado, 2004, pp. 156–159.
- Hedderson, E.L., Newton, J.R., 2004. Prospects for vaccination against equine grass sickness. *Equine Veterinary Journal* 36, 186–191.
- Hillyer, M.H., Taylor, F.G., French, N.P., 2001. A cross-sectional study of colic in horses on thoroughbred training premises in the British Isles in 1997. *Equine Veterinary Journal* 33, 380–385.
- Hillyer, M.H., Taylor, F.G., Proudman, C.J., Edwards, G.B., Smith, J.E., French, N.P., 2002. Case control study to identify risk factors for simple colonic obstruction and distension colic in horses. *Equine Veterinary Journal* 34, 455–463.
- Hudson, J.M., Cohen, N.D., Gibbs, P.G., Thompson, J.A., 2001. Feeding practices associated with colic in horses. *Journal of the American Veterinary Medical Association* 219, 1419–1425.
- Hunter, L.C., Miller, J.K., Poxton, I.R., 1999. The association of *Clostridium botulinum* type C with equine grass sickness: a toxicoinfection. *Equine Veterinary Journal* 31, 492–499.
- Kaneene, J.B., Miller, R., Ross, W.A., Gallagher, K., Marteniuk, J., Rook, J., 1997. Risk factors for colic in the Michigan (USA) equine population. *Preventative Veterinary Medicine* 30, 23–36.
- Little, D., Blikslager, A.T., 2002. Factors associated with development of ileal impaction in horses with surgical colic: 78 cases (1986–2000). *Equine Veterinary Journal* 34, 464–468.
- Lorenzo-Figueras, M., Merritt, A.M., 2002. Effects of exercise on gastric volume and pH in the proximal portion of the stomach of horses. *American Journal of Veterinary Research* 63, 1481–1487.
- Lyons, E.T., Drudge, J.H., Tolliver, S.C., 2000. Larval cyathostomiasis. *Veterinary Clinics of North America Equine Practice* 16, 501–513.
- Mair, T.S., 2004. BEVA evidence-based medicine colic survey. In: *Proceedings British Equine Veterinary Association congress 2004*, Birmingham, UK, pp. 58–59.
- Mair, T.S., Sutton, D.G.M., Love, S., 2000. Caecocolic and caecocolic intussusceptions associated with larval cyathostomiasis in four young horses. *Equine Veterinary Journal*, Supplement 32, 77–80.
- McCarthy, H.E., Proudman, C.J., French, N.P., 2001. The epidemiology of equine grass sickness – a literature review (1909–1999). *Veterinary Record* 149, 293–300.
- McCarthy, H.E., French, N.P., Edwards, G.B., Poxton, I.R., Kelly, D.F., Payne-Johnson, C.E., Miller, K., Proudman, C.J., 2004a. Equine grass sickness is associated with low antibody levels to *Clostridium botulinum*: a matched case-control study. *Equine Veterinary Journal* 36, 123–129.
- McCarthy, H.E., French, N.P., Edwards, G.B., Miller, K., Proudman, C.J., 2004b. Why are certain premises at increased risk of equine grass sickness. A matched case-control study. *Equine Veterinary Journal* 36, 130–134.
- McClure, S.R., Glickman, L.T., Glickman, N.W., 1999. Prevalence of gastric ulcers in show horses. *Journal of the American Veterinary Medical Association* 215, 1130–1133.
- Murray, M.J., 1989. Endoscopic appearance of gastric lesions in foals: 94 cases (1987–1988). *Journal of the American Veterinary Medical Association* 195, 1135–1141.
- Murray, M.J., 1994. Equine model of inducing ulceration in alimentary squamous epithelial mucosa. *Digestive Diseases and Sciences* 39, 2530–2535.
- Murray, M.J., Eichorn, E.S., 1996. Effects of intermittent feed deprivation, intermittent feed deprivation with ranitidine administration, and stall confinement with ad libitum access to hay on gastric ulceration in horses. *American Journal of Veterinary Research* 57, 1599–1603.
- Murray, M.J., Schusser, G.F., Pipers, F.S., Gross, S.J., 1996. Factors associated with gastric lesions in Thoroughbred racehorses. *Equine Veterinary Journal* 28, 368–374.
- Nadeau, J.A., Andrews, F.M., Mathew, A.G., Argenzio, R.A., Blackford, J.T., Sohtell, M., Saxton, A.M., 2000. Evaluation of diet as a cause of gastric ulcers in horses. *American Journal of Veterinary Research* 617, 84–90.
- Newton, J.R., Hedderson, E.J., Adams, V.J., McGorum, B.C., Proudman, C.J., Wood, J.L.N., 2004. An epidemiological study

- of risk factors associated with the recurrence of equine grass sickness (dysautonomia) on previously affected premises. *Equine Veterinary Journal* 36, 105–112.
- Nicol, C.J., Davidson, H.P., Harris, P.A., Waters, A.J., Wilson, A.D., 2002. Study of crib-biting and gastric inflammation and ulceration in horses. *Veterinary Record* 151, 658–662.
- Nieto, J.E., Snyder, J.R., Beldomenico, P., Aleman, M., Kerr, J.W., Spier, S.J., 2004. Prevalence of gastric ulcers in endurance horses – a preliminary report. *The Veterinary Journal* 167, 33–37.
- Proudman, C.J., 1991. A two year, prospective survey of equine colic in general practice. *Equine Veterinary Journal* 24, 90–93.
- Proudman, C.J., Holdstock, N.B., 2000. Investigation of an outbreak of tapeworm-associated colic in a training yard. *Equine Veterinary Journal*, Supplement 32, 37–41.
- Proudman, C.J., Trees, A.J., 1999. Tapeworms as a cause of intestinal disease in horses. *Parasitology Today* 15, 156–159.
- Proudman, C.J., French, N.P., Trees, A.J., 1998. Tapeworm infection is a significant risk factor for spasmodic colic and ileal impaction colic in the horse. *Equine Veterinary Journal* 30, 194–199.
- Rabuffo, T.S., Orsini, J.A., Sullivan, E., Englies, J., Norman, T., Boston, R., 2002. Association between age or sex and prevalence of gastric ulceration in Standardbred racehorses in training. *Journal of the American Veterinary Medical Association* 221, 1156–1159.
- Ragle, C.A., Meagher, D.M., Lacroix, C.A., Honnas, C.M., 1989. Surgical treatment of sand colic; results in 40 horses. *Veterinary Surgery* 18, 48–51.
- Reeves, M.J., 1997. What really causes colic in horses. Epidemiology's role in elucidating the ultimate multifactorial disease? *Equine Veterinary Journal* 29, 413–414.
- Reeves, M.J., Gay, J.M., Hilbert, B.J., Morris, R.S., 1989. Association of age, sex and breed factors in acute equine colic: A retrospective study of 320 cases admitted to a veterinary teaching hospital in the USA. *Preventative Veterinary Medicine* 7, 149–160.
- Reeves, M.J., Salman, M.D., Smith, G., 1996. Risk factors for equine acute abdominal disease (colic): Results from a multi-centre case-control study. *Preventative Veterinary Medicine* 26, 285–301.
- Reid, S.W., Mair, T.S., Hillyer, M.H., Love, S., 1995. Epidemiological risk factors associated with a diagnosis of clinical cyathostomiasis in the horse. *Equine Veterinary Journal* 27, 127–130.
- Schlesselman, J.J., 1982. Basic concepts in the assessment of risk. In: *Case-control Studies: Design, Conduct, Analysis*. Oxford University Press, Oxford, pp. 27–68.
- Southwood, L.L., Ragle, C.A., Snyder, J.R., 2002. Surgical treatment of ascarid impactions in foals and horses. In: *Proceedings of the Seventh International Equine Colic Research Symposium Manchester, UK*, pp. 112–113.
- Tinker, M.K., White, N.A., Lessard, P., Thatcher, C.D., Pelzer, K.D., Davis, B., Carmel, D.K., 1997a. A prospective study of equine colic incidence and mortality. *Equine Veterinary Journal* 29, 448–453.
- Tinker, M.K., White, N.A., Lessard, P., Thatcher, C.D., Pelzer, K.D., Davis, B., Carmel, D.K., 1997b. A prospective study of equine colic risk factors. *Equine Veterinary Journal* 29, 454–458.
- Tocher, J.F., Brown, W., Tocher, J.W., Buxton, J.B., 1923. 'Grass sickness' investigation report. *Veterinary Record* 3, 37–45, 75–89.
- Traub-Dargatz, J.L., Koprak, C.A., Seitzinger, A.H., Garber, L.P., Forde, K., White, N.A., 2001. Estimate of the national incidence of and operation-level risk factors for colic among horses in the United States, spring 1998 to spring 1999. *Journal of the American Veterinary Medical Association* 219, 67–71.
- Uhlinger, C., 1990. Effects of three anthelmintic schedules on the incidence of colic in horses. *Equine Veterinary Journal* 22, 251–254.
- Vatistas, N.J., Sifferman, R.L., Holste, J., Cox, J.L., Pinalto, G., Schultz, K.T., 1999a. Induction and maintenance of gastric ulceration in horses in simulated race training. *Equine Veterinary Journal* Supplement 29, 40–44.
- Vatistas, N.J., Snyder, J.R., Carlson, G., Johnson, B., Arthur, R.M., Thurmond, M., Zhou, H., Lloyd, K.L., 1999b. Cross-sectional study of gastric ulcers of the squamous mucosa in Thoroughbred racehorses. *Equine Veterinary Journal* Supplement 29, 34–39.
- White, N.A., 1997. Risk factors associated with colic. In: *Robinson, N.E. (Ed.), Current Therapy in Equine Medicine*, fourth ed. W.B. Saunders Co, Philadelphia, pp. 174–179.
- Wood, J.L.N., Milne, E.M., Doxey, D.L., 1998. A case-control study of grass sickness (equine dysautonomia) in the United Kingdom. *The Veterinary Journal* 156, 7–14.